

# W8 Hull and machinery steel castings

(1978)  
(Rev.1  
July 2002)  
(Rev.2  
May 2004)  
(Rev.3  
Mar 2022)

## 1 Scope

1.1 These requirements are applicable to C, C-Mn and alloy steel castings intended for hull and machinery applications for ships and offshore units for worldwide services as specified in the relevant IACS Unified requirements and/or requirements of the Classification Society. This Unified Requirement also makes consideration for grades that are intended for fabrication by welding, as well as grades not intended for welding.

1.2 Additional requirements may be necessary, especially when the castings are intended for service at low or elevated temperatures, e.g. for ships with ice-class or for boilers. Additional requirements will typically be required for castings for offshore units depending on applicable service temperature and environment.

1.3 Similarly, C and C-Mn steel castings and alloy steel castings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or are otherwise specially approved or required by the Classification Society.

## 2 Manufacture

2.1 Castings are to be made at a manufacturer approved by the Classification Society.

2.2 The steel is to be manufactured by a process approved by the Classification Society.

2.3 All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognized good practice and is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the chemical composition and/or thickness of the castings. If necessary, the affected areas are to be either machined or ground smooth.

2.4 For certain components including steel castings subjected to surface hardening process, the proposed method of manufacture may require special approval by the Classification Society.

2.5 Joining of two or more castings by welding to form a composite component: Requirements for welding procedure qualification tests of steels for hull construction and marine structures are specified in UR W28. Welders for hull structural steel castings are to be qualified in accordance with UR W32. Requirements for other WPS and qualification thereof, for welder certification and for type approval of welding consumables are at the discretion of the Class Societies.

2.6 Temporary welds made for operations such as lifting, handling, staging, etc., are to be in accordance with approved welding procedures and qualified welders, and are to be removed, ground and inspected using suitable NDT methods.

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### Notes:

1. Rev.3 of this UR is to be uniformly implemented by IACS Societies for ships and offshore units contracted for construction on or after 1 July 2023.

### 3 Quality of castings

3.1 All castings are to be free from surface or internal defects, which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

### 4 Chemical composition

4.1 All castings are to be made from killed steel and the chemical composition is to be appropriate for the type of steel and the mechanical properties specified for the castings.

4.1 The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

4.2 The chemical composition is to comply with the overall limits given in Table 1 and Table 2, respectively, or, where applicable, the requirements of the approved specification.

**Table 1** Chemical composition limits for hull and machinery steel castings (%): C, C-Mn steels

Steel type	Applications	C (max.)	Si (max.)	Mn	S (max.)	P (max.)	Residual elements (max.)				Total residuals (max.)
							Cu	Cr	Ni	Mo	
C, C-Mn	Castings for non-welded construction	0.40	0.60	0.50-1.60	0.035	0.035	0.30	0.30	0.40	0.15	0.80
	Castings for welded construction	0.23	0.60	0.50-1.60	0.035	0.035	0.30	0.30	0.40	0.15	0.80

**Table 2** Chemical composition limits for hull and machinery steel castings (%): Alloy steels

Steel type	Applications	C (max.)	Si (max.)	Mn	S (max.)	P (max.)	Alloying elements <sup>1)</sup> (min.)			
							Cu	Cr	Ni	Mo
Alloy	Castings for non-welded construction	0.45	0.60	0.50-1.60	0.030	0.035	0.30	0.40	0.40	0.15
	Castings for welded construction	alloying element values to be agreed with Class Society								
<sup>1)</sup> At least one of the elements shall comply with the minimum content.										

4.3 Suitable grain refining elements such as aluminium may be used at the discretion of the manufacturer or as agreed with the Class Society.

### 5 Heat treatment (including straightening)

5.1 Castings are to be supplied in one of the following delivery conditions:

- (a) Carbon and carbon-manganese steels:
- Fully annealed
  - Normalized

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- Normalized and tempered
  - Quenched and tempered.
- (b) Alloy steels:
- Normalized
  - Normalized and tempered
  - Quenched and tempered

For all types of steel the tempering temperature is to be not less than 550°C.

The delivery condition shall meet the design and application requirements. It is the manufacturers responsibility to select the appropriate heat treatment method to obtain the required mechanical properties.

5.2 Castings for components such as crankshafts and engine bedplates, where dimensional stability and freedom from internal stresses are important, are to be given a stress relief heat treatment. This is to be carried out at a temperature of not less than 550°C followed by furnace cooling to 300°C or lower.

5.3 Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole casting to be uniformly heated to the necessary temperature. In the case of very large castings alternative methods for heat treatment will be specially considered by the Classification Society. Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.

5.4 If a casting is locally reheated or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses. The manufacturer shall have strict control of this temperature in order to avoid any detrimental effects to the final heat treatment and resultant microstructure and mechanical properties of the casting.

5.5 The foundry is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records are to be presented to the Surveyor on request.

## **6 Mechanical tests**

6.1 Test material, sufficient for the required tests and for possible retest purposes is to be provided for each casting or batch of castings.

6.2 At least one test block is to be provided for each casting. Unless otherwise agreed these test blocks are to be either integrally cast or gated to the castings.

6.3 The size of the test blocks for mechanical testing is to be such that the heat treatment and microstructure is representative for the section of the casting with the ruling section, i.e. the section for which the specified mechanical properties apply, see also ISO 683-1:2018 and ISO 683-2:2018, respectively.

For C, C-Mn steel castings this is in general to be achieved as follows:

The test block shall have a thickness ( $t_s$ ) of not less than the ruling section of the casting, or 30 mm, whichever is larger.

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For large thickness castings other than stern tube, stern frame, anchor and rudder horn,  $t_s$  normally need not to exceed 150 mm. Length and width of the test block is normally to be at least three times  $t_s$ , unless otherwise agreed with the Class Society, as shown in Figure 1. (Note that longer or wider test blocks may be necessary in order to accommodate the required test specimens.)

For castings for stern tube, stern frame, anchor and rudder horn the test block thickness  $t_s$  shall represent the ruling section.

### Guidance:

Shorter width or length may be accepted for test blocks where actual casting width or length ( $t_A$ ) is in the range between  $t_s$  and  $3t_s$ .

Example 1: For a general casting with dimensions 140 x 160 x 1250 mm the required test block size would typically be 140 x 160 x 420 mm (that is:  $t_s \times t_A \times 3t_s$ ).

Example 2: For a stern tube casting with ruling section  $t_s = 170$  mm and width/height/length  $t_{A1}/t_{A2}/t_{A3} = 1000/600/1800$  mm, the required test block size would typically be 170 x 510 x 510 mm (that is:  $t_s \times 3t_s \times 3t_s$ ) see Figure 2.

(end of guidance)

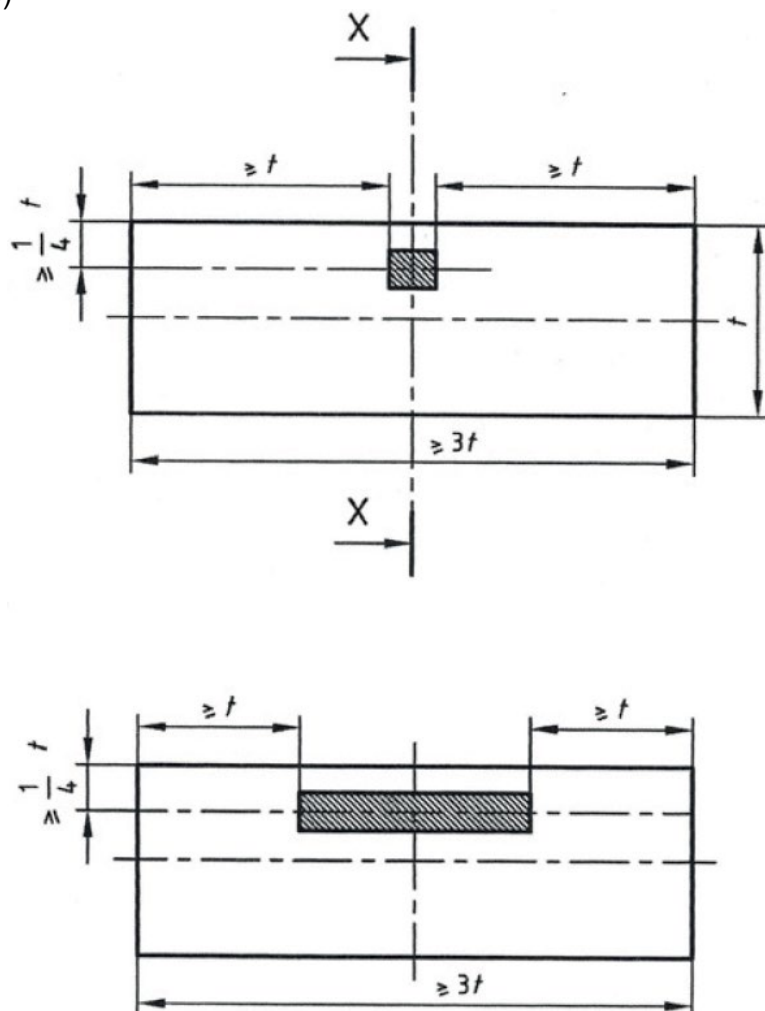


Fig. 1: Specimen positions relative to the test block in accordance with ISO 4990:2015\*

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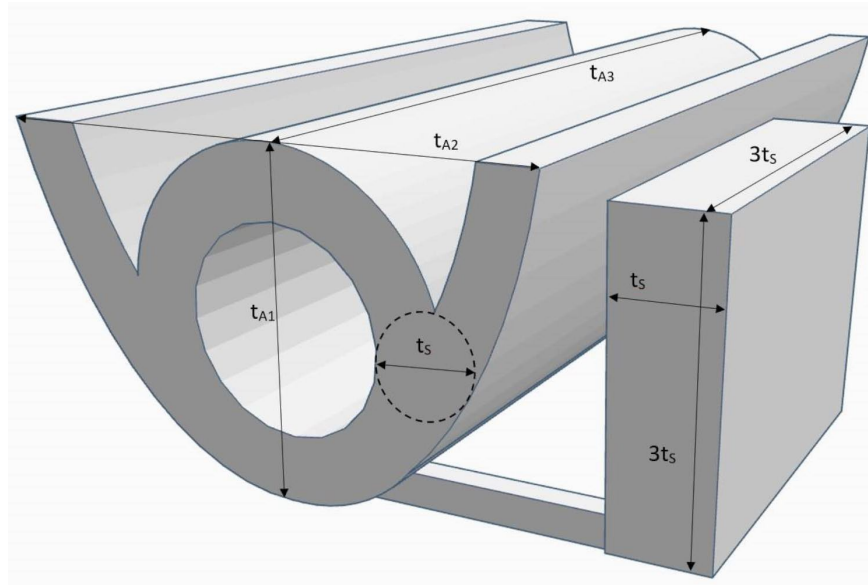


Fig. 2: Example 2: test block gated to stern tube casting

For alloy steel castings the manufacturer shall propose dimensions for the test block and demonstrate the representative nature of it.

6.4 For test blocks with thickness  $\leq 56$  mm, the longitudinal axis of the test specimens is to be located at  $\geq 14$  mm from the surface in the thickness direction. For test blocks with thickness  $> 56$  mm, the longitudinal axis of the test specimens is to be located at  $\geq \frac{1}{4} t_s$  from the surface. Test specimens shall be taken in such a way that no part of the gauge length is machined from material closer than  $t_s$  to any of the other surfaces. For impact testing, this requirement shall apply to the complete test specimen - refer to Figure 1 for location of test specimens in relation to the test block.

6.5 Where the casting is of complex design or where the finished mass exceeds 10 tonnes, two cast on test blocks are to be provided from the heaviest section, located as far as practicable from each other.

6.6 Where large castings are made from two or more casts, which are not mixed in a ladle prior to pouring, two or more test blocks are to be provided corresponding to the number of casts involved. These are to be integrally cast at locations as widely separated as possible.

6.7 For castings where the method of manufacture has been specially approved by the Classification Society in accordance with W8.2.4, the number and position of test blocks is to be agreed with the Classification Society having regard to the method of manufacture employed.

6.8 As an alternative to 6.2, where a number of small castings of about the same size, each of which is under 1000kg in mass, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test blocks of suitable dimensions. At least one test block is to be provided for each batch of castings.

6.9 The test blocks are not to be detached from the casting until the specified heat treatment has been completed and they have been properly identified.

6.10 One tensile test specimen and one set of impact tests are to be taken from each test block.

6.11 The preparation of test specimens and the procedures used for mechanical testing are to comply with the relevant requirements of UR W2. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyors.

## 7 Mechanical properties

7.1 Table 3 and Table 4 give the minimum requirements for yield stress, elongation, reduction of area and impact test energy values corresponding to steel types and different strength levels. Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given, corresponding minimum values for the other properties may be obtained by interpolation.

7.2 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 3 and Table 4, respectively, but subject to any additional requirements of the relevant construction Rules.

7.3 The mechanical properties are to comply with the requirements of Table 3 and Table 4, respectively, appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

7.4 Re-test requirements for tensile tests are to be in accordance with UR W2.

7.5 The additional tests detailed in 7.4 are to be taken, preferably from the same, but alternatively from another, test block representative of the casting or batch of castings.

7.6 At the option of the manufacturer, when a casting or batch of castings has failed to meet the test requirements, it may be reheat treated and re-submitted for acceptance tests.

**Table 3** Mechanical properties for steel castings intended for welding

Steel type	Specified minimum tensile strength <sup>1)</sup> ( $N/mm^2$ )	Yield stress ( $N/mm^2$ ) min.	Elongation on $5,65 \sqrt{S_0}$ (%) min.	Reduction of area (%) min.	Charpy V-notch impact	
					Test temperature (°C)	Minimum average energy (J)
C, C-Mn	400	200	25	40	0	27
	440	220	22	30		
	480	240	20	27		
	520	260	18	25		
	560	300	15	20		
	600	320	13	20		
Alloy	550	355	18	30	0	27
	600	400	16	30		
	650	450	14	30		
	700	540	12	28		

NOTE

<sup>1)</sup> A tensile strength range of  $150 N/mm^2$  may additionally be specified.

<sup>2)</sup> Special consideration may be given to alternative requirements for Charpy V-notch impact test, depending on design and application, and subject to agreement by Society.

**Table 4.** Mechanical properties for machinery steel castings not intended for welding

Steel type	Specified minimum tensile strength <sup>1)</sup> ( $N/mm^2$ )	Yield stress ( $N/mm^2$ ) min.	Elongation on 5,65 $\sqrt{S_0}$ (%) min.	Reduction of area (%) min.	Charpy V-notch impact test <sup>2)</sup>	
					Test temperature ( $^{\circ}C$ )	Minimum average energy (J)
C, C-Mn	400	200	25	40	AT <sup>3)</sup>	27
	440	220	22	30		
	480	240	20	27		
	520	260	18	25		
	560	300	15	20		
	600	320	13	20		
Alloy	550	340	16	35	AT <sup>3)</sup>	27
	600	400	16	35		
	650	450	14	32		
	700	540	12	28		

NOTE

1) A tensile strength range of 150  $N/mm^2$  may additionally be specified.

2) Special consideration may be given to alternative requirements for Charpy V-notch impact test, depending on design and application, and subject to agreement by Society.

3) AT refers to Ambient Temperature (i.e.  $23^{\circ}C \pm 5^{\circ}C$ ), which is specified in ISO 148-1:2016

## 8 Inspection

8.1 All castings are to be cleaned and adequately prepared for examination; suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

8.2 Before acceptance all castings are to be presented to the Surveyors for visual examination. Where applicable, this is to include the examination of internal surfaces. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

8.3 When required by the relevant construction Rules, or by the approved procedure for welded composite components (see W8.2.6.), appropriate non-destructive testing is also to be carried out before acceptance and the results are to be reported by the manufacturer. The extent of testing and acceptance criteria are to be agreed with the Classification Society. IACS Recommendation No. 69 is regarded as an example of an acceptable standard specifying suitable minimum requirements.

8.4 When required by the relevant construction Rules castings are to be pressure tested before final acceptance. These tests are to be carried out in the presence of the Surveyor and are to be to their satisfaction.

8.5 In the event of any casting proving to be defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

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(cont)**9 Rectification of defective castings****9.1 General**

- (i) Where castings are to be repaired, the manufacturer shall exercise robust controls of all repair operations regarding the repair of castings, with respect to dimensions, heat treatment, inspection and quality control.
- (ii) The approval of the Classification Society is to be obtained where steel castings from which defects were removed are to be used with or without weld repair.
- (iii) Defects and unacceptable indications must be repaired as indicated below:  
Defective parts of material may be removed by grinding, or by chipping and grinding, or by arc air-gouging and grinding. Thermal methods of metal removal shall only be allowed before the final heat treatment. All grooves shall have a bottom radius of approximately three times the groove depth and should be smoothly blended to the surface area with a finish equal to that of the adjacent surface.
- (iv) For NDT of steel castings after repair, see 8.3.
- (v) Where the defective area is to be repaired by welding, the excavations are to be suitably shaped to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to be verified by MT or PT.
- (vi) Shallow grooves or depressions resulting from the removal of defects may be accepted provided that they will cause no appreciable reduction in the strength of the casting or affect the intended use, and the depth of defect removal is not over 15mm or 10% of wall thickness, whichever is less. The resulting grooves or depressions are to be subsequently ground smooth and complete elimination of the defective material is to be verified by MT or PT. Small surface irregularities sealed by welding are to be treated as weld repairs, see 9.2.

**9.2 Weld Repairs**

In addition to the requirements given in 9.1, the following apply for weld repairs:

- (i) For C and C-Mn steel castings weld repairs shall be suitably classified as major or minor. For alloy steel castings, repair requires approval from the Classification Society.
  - a. Major repairs are those where:
    - the depth is greater than 25% of the wall thickness or 25mm whichever is less, or
    - the total weld area on a casting exceeds  $0.125\text{m}^2$  of the casting surface noting that where a distance between two welds is less than their average width, they are to be considered as one weld.
  - b. Minor weld repairs: Weld repairs not classified as major are considered as minor and need to be carried out in accordance with a qualified welding procedure.
- (ii) The following is required for major repairs:
  - a. Shall be carried out before the final delivery heat treatment condition
  - b. Shall comply with the requirements in (iv) below



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- c. Before welding is started, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for approval.
- (iii) The following is required for minor repairs:
- Shall be carried out before the final delivery heat treatment condition
  - Shall comply with the requirements in (iv) below (also with respect to records, see (iv) f) and g).
  - With the exception of alloy steels, do not require prior approval by the Classification Society, except as given in (d)
  - The Classification Society may request minor repairs in critical areas to be treated as major repairs.
- (iv) The following requirements apply for all weld repairs (major and minor):
- All castings in alloy steels and all castings for crankshafts are to be suitably pre-heated prior to welding. Castings in carbon or carbon-manganese steel may also require to be pre-heated depending on their chemical composition and the dimensions and position of the weld repairs.
  - Welding procedures are to be qualified and shall match the delivery condition of the casting. Qualification of welding procedures shall follow the Classification Society rules, or subject to agreement with the Classification Society, a recognised standard (e.g. IACS UR W28 or ISO 11970:2016).
  - Welding is to be done under cover in positions free from draughts and adverse weather conditions by qualified welders with adequate supervision. As far as possible, all welding is to be carried out in the downhand (flat) position.
  - The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in 5.1.
  - After welding has been completed the castings are to be given either a suitable heat treatment in accordance with the requirements of 5.1 or a stress relieving heat treatment at a temperature of not less than 550°C for C and C-Mn steel castings. For alloy steel castings, the heat treatment has to be agreed with the Classification Society. The type of heat treatment employed will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs, and should not affect the properties of the casting.
- Subject to the prior agreement of Classification Society, special consideration may be given to the omission of post weld heat treatment or to the acceptance of local stress-relieving heat treatment where the repaired area is small and machining of the casting has reached an advanced stage.
- On completion of heat treatment the weld repairs and adjacent material are to be ground smooth and examined by magnetic particle or liquid penetrant testing. Supplementary examination by ultrasonics or radiography ultrasonic or

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radiographic testing may also be required depending on the dimensions and nature of the original defect. Satisfactory results are to be obtained from all forms of non-destructive testing used.

- g. The manufacturer is to maintain full records detailing the extent and location of repairs made to each casting and details of weld procedures and heat treatments applied for repairs. These records are to be available to the Surveyor and copies provided on request.

9.3 Recommendation for welding: For steels with  $C \geq 0.23$  or  $C_{eq} \geq 0.45$ , the WPQT on which the WPS is based, should be qualified on a base material having a  $C_{eq}$  as follows: the  $C_{eq}$  of the base material should not fall below more than 0.02 of the material to be welded. (Example: WPQT for a material with actual  $C_{eq} = 0.50$  may be qualified on a material with  $C_{eq} \geq 0.48$ .)

**10 Identification of castings**

10.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and the Surveyors are to be given full facilities for so tracing the castings when required.

10.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer. At the discretion of individual Classification Societies any of the following particulars may be required:

- (i) Steel quality.
- (ii) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
- (iii) Manufacturer's name or trade mark.
- (iv) The Classification Society's name, initials or symbol.
- (v) Abbreviated name of the Classification Society's local office.
- (vi) Personal stamp of Surveyors responsible for inspection.
- (vii) Where applicable, test pressure.

10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Classification Society.

**11 Certification**

11.1 The manufacturer is to provide the required type of inspection certificate giving the following particulars for each casting or batch of castings which has been accepted:

- (i) Purchaser's name and order number.
- (ii) Description of castings and steel quality.
- (iii) Identification number.
- (iv) Steel making process, cast number and chemical analysis of ladle samples.
- (v) Results of mechanical tests.
- (vi) Results of non-destructive tests, where applicable.
- (vii) Details of heat treatment, including temperatures and holding times.
- (viii) Where applicable, test pressure.

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